CEBAF PROPOSAL COVER SHEET

This Proposal must be mailed to:

CEBAF
Scientific Director's Office
12000 Jefferson Avenue
Newport News, VA 23606

and received on or before OCTOBER 30, 1989

A. TITLE:

ELECTROPRODUCTION OF KAONS AND LIGHT HYPERNUCLEI

B. CONTACT PERSON:

B. Zeidman

ADDRESS, PHONE AND BITNET:

Physics Division-203
Argonne National Laboratory, Argonne, IL 60439-4843
(312) 972-4027 Bitnet: ZEIDMAN@anlphy

C. THIS PROPOSAL IS BASED ON A PREVIOUSLY SUBMITTED LETTER OF INTENT

- [x] YES
- [ ] NO

IF YES, TITLE OF PREVIOUSLY SUBMITTED LETTER OF INTENT

ELECTROPRODUCTION OF KAONS AND LIGHT HYPERNUCLEI

D. ATTACH A SEPARATE PAGE LISTING ALL COLLABORATION MEMBERS AND THEIR INSTITUTIONS

===

(CEBAF USE ONLY)

Letter Received 10-30-89

Log Number Assigned PR-89-013

By KES

contact: Zeidman

CEBAF Experiment Requirements

Date Submitted __/__

Title & Spokesperson Electroproduction of Kaons and Light Hypernuclei

B. Zeidman

Estimated total beam time (hours)	750	
Electron beam energy(s) required	2.5	3.0
Beam current(s) (μA)	15	15
Total μA-hours required	1000	8000
Solid target(s) material	–	
Solid target(s) thickness	–	
Cryogenic target -type and length (cm)	Liquid 1.5 cm	Gas 10 cm
Power deposition in cryogenic target (Watts)	Approx. 3 watts	
Polarized beam (y/n)	n	
Polarized target (y/n)	n	
Power deposition in polarized target	–	
Effective beam spot diameter (≥100 microns)	1 mm	
Scanned beam at target (y/n)	n	
Dispersed beam (y/n)	n	

Spectrometer Requirements	*e' Arm*	*Hadron Arm*
Solid angle acceptance (msr)	5.0	9.0
Momentum acceptance (FWHM %)	10	40
Momentum resolution (FWHM %)	0.1	0.1
Scattering angle (degrees)		
Minimum	12.5	12.5
Maximum	20	30
Scattering angle, uncertainty (mr)	0.5	2.0
Central orbit momenta (MeV/c)		
Minimum	500	00
Maximum	2000	1700
Spectrometer settings, reproducibility,		
Central angle (mr)	0.5	1
Central momentum (MeV/c)	1	1
Particle identification requirements		
Rejection type (e.g. π^-/e^-)	π^-/e^-	π^+/K^+
Required ratio (e.g. 10^{-3})	10^2 reject π^-	$10^4/1$ reject
Traceback capability required (y/n)	y	

Position accuracy along beam (mm)	10
Luminosity range ($cm^{-2}\ sec^{-1}$)	4×10^{36}

Remarks:

October 24, 1989

RESEARCH PROPOSAL

ELECTROPRODUCTION OF KAONS AND LIGHT HYPERNUCLEI

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ABSTRACT

The study of the structure of nuclei containing strange baryons is one of the frontier areas of nuclear research which may provide critical information concerning modifications of simple degrees of freedom in the many body nuclear medium. Electroproduction of light hypernuclei on targets in the 1s-shell is a relatively distortion free method of investigating the fundamental Λ-nucleon interactions that are critical for understanding complex hypernuclei since both the electron and K^+ are weakly interacting particles. The projected program requires coincident detection of the emergent e and k^+ in moderate resolution magnetic spectrometers that are able to provide suitable angular resolution over reasonably large solid angles, i.e. HMS and SOS in Hall C. In addition to elucidating the kaon-nucleon-hyperon coupling constants, the study will investigate a theoretically predicted cusp near the sigma threshold.

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hyperon-nucleon effective interaction in complex nuclei without the need for very high resolution and excessively long running times.

In recent years, there have been a number of theoretical discussions of the d(e,e'K) reaction, particularly in the proceedings of CEBAF summer workshops.[1] Cotanch,[2] Donnelly,[1] et al. have shown that a careful study of electroproduction of kaons on deuterium, as well as on the proton, will provide important information about the K-nucleon-Y coupling constants, where Y is either lambda or sigma, and a unique method for studying Y-nucleon interactions. Of particular interest is a theoretically predicted[2] cusp in the inclusive kaon cross section for an invariant missing mass of roughly 2.13 GeV, shown in Fig. 1. This cusp, also reflected in strong mass dependent changes in the kaon angular distribution displayed in Fig. 2, is near the sigma threshold and depends upon the unknown relative phase between the lambda and sigma elementary production amplitudes. Even more interesting, and speculative, possibilities are strangeness -1 dibaryons predicted[3] to have masses just above and below the sigma threshold.

Bound, or nearly bound, hypernuclear states are produced by $(e,e'K^+)$ reactions on ^3He and ^4He where the beginnings of interactions in a nuclear medium may be investigated. Two states have been predicted in the hydrogenic mass 4 hypernucleus, a strong 1^+ state and a weak 0^+ state that should be very sensitive to variations in the elementary amplitudes.[2] A weak coupling description of the corresponding mass 3 hypernucleus suggests three states, a 3/2 state and two 1/2 states, at least one of which is bound. Studies of heavier nuclei, while of potentially greater interest at a later date, for reasons to be discussed below appear to be more difficult in the early stages of the CEBAF experimental program.

EXPERIMENT

The experiment involves coincident detection of an inelastically scattered electron and a kaon, i.e. an $(e,e'K^+)$ reaction. The targets would consist of cooled gas or liquid H, D, ^3He, and ^4He. As has been discussed previously[1,2] the flux of virtual photons is maximized by scattering at a far forward angle and the coincidence count rates are maximized when the kaons are detected at angles close to the direction of the photon. Since the reaction involves three body (or more) final states, each detector covers a broad range of energies for a given final state. The choice of electron angle is limited by the bremsstrahlung peak near zero degrees, multiple scattering, and singles counting rates, but a forward angle is clearly preferred; physical dimensions of the spectrometers proposed for Hall C will restrict the study to angles greater than 12 degrees. The kaon angle, e.g. as seen in the Fig. 2, covers a range from far forward angles to about 30 degrees, but the direction of the virtual photon is shifted to larger angles for the present choice of electron scattering angle and energy range, albeit at a price in counting rate. For the kinematics shown in Fig. 2, the virtual photon angle is $<5°$ and the kaon cross section decreases rapidly for $\theta_K>5°$. In the present study the detection of electrons at a larger angle results in virtual photons whose directions are roughly centered about 12.5°, depending upon the energy of the scattered electron. The particular advantage of light nuclei is that the relatively large intrinsic cross sections allow some reduction in count rate without introducing excessive running times.

Count rate estimates are based upon utilization of the spectrometers that have been discussed for Hall C, namely HMS and SOS. Target thickness of 5×10^{22} atom/cm^2 and average current of 15 microamps are assumed. While higher luminosity could be achieved easily, the rate random e-K coincidences becomes excessive; the electron singles rates would be $<5\times10^4$/sec, the K^+ singles from quasifree production $<5\times10^2$/sec for all of the targets being considered. The kaon angles will vary from nearly that of the virtual photon to about 15° relative to the photon. For heavier targets, cross sections for hypernuclear states are roughly comparable, but the random rates increase rapidly. A listing of representative count rates, beam energies and angles is presented in the Table I. Under these conditions, the true to random coincidence ratio varies from ~15, for deuterium to ~3, for ^{4}He. The cross sections, shown in the figures, were obtained from Refs. 1 and 2, rates estimated for the spectrometers proposed for Hall C, and running times calculated at the various angles and beam energies. The run times are determined by the predicted increase (decrease) of the yield in the vicinity of the cusp shown in Fig. 1, and the cross sections assumed for the counting rates are those in the vicinity of the minimum of the cross section. A 10% measurement of the "difference" in cross section will therefore require about 50 hours. The large dynamic range of both SOS and HMS allows the data to be accumulated over the entire mass spectrum with, at most, two momentum settings at each angle.

The primary objective of the experiment is to investigate the deuteron. For this target, there will be runs at several energies at the minimum spectrometer angles, 12.5°, and data obtained for 3.0 GeV electrons at additional kaon angles of 15.5, 18.5 and a larger angle (if possible). The total time for this target would be approximately 450 hours when the overlap between momentum settings is taken into account. The other targets, ^{4}He and ^{3}He, would be surveyed to obtain yield data so that an additional 300 hours would be desirable. If the raw trigger rate can be increased (to be discussed below) more beam intensity may be used and the estimated run time might be decreased.

The major issues to be addressed are the identification of kaons in the presence of many more pions, $\pi/k \lesssim 10^4$, and maintenance of a high ~10/1 ratio of real to random k-e coincidences. Both of these issues require a relatively sophisticated detector package for the kaon arm; the electron arm needs only a standard detector package.

Since ~10^4 pion rejection is desired, it is necessary to utilize a two-level pion-kaon rejection mode. The SOS spectrometer provides a direct measure of the momentum of the "kaon". As indicated in Table I kaon momenta range from ~0.6 to 1.65 GeV/c; β for kaons, pions, and protons are listed in Table II. Over this range, $\beta_\pi>0.974$ while $\beta_K<0.96$. Use of an aerogel Cerenkov threshold counter with n=1.03 should provide $>10^2$ pion rejection. At the higher momenta, the aerogel should be particularly effective and efficient.

Utilization of the time-of-flight, TOF, through the SOS spectrometer provides the second mode of pion rejection as well as excellent proton ideentification. As indicated in Table II, the TOF differences between pions and kaons are always >1 ns. Both the HMS and SOS detector packages will be equipped with scintillator hodoscopes capable of providing ~300 ps timing resolution. The TOF in SOS will be obtained relative to the electron detected in HMS. (Relative time $\lesssim$300 ps was demonstrated by many members of the present collaboration in SLAC experiment NE8.) Use of the TOF technique should provide $>10^2$ pion rejection, particularly at momenta <1.5 GeV/c. The combination of threshold Cerenkov and TOF pion and proton rejection should therefore provide clean kaon spectra after software corrections have been made.

Reduction of random kaon-electron coincidences is also effected through the use of TOF techniques, but care must be taken at the raw trigger level mentioned earlier. Depending upon momentum, the relative k-e timing,

$\Delta t(k-e)$, varies over 6 ns, as is seen in Table II. In addition, the actual flight time in both spectrometers depends upon the angle relative to the central trajectory, i.e. out-of-plane angle. This angular dependence, independent of momentum, introduces an additional 0.8 ns variation. Various hardware techniques can be used to reduce the effective variations to ~3 ns in the raw hardware trigger. This is the value used for the random coincidence calculations listed in Table I. If this trigger rate is well below the system capability, the beam intensity may be increased to obtain a higher true rate.

After software corrections, i.e. momentum determination, TOF correction, angle determination, etc., the timing resolution is expected to be better than 500 ps. It is at this level that a major fraction of random coincidences may be rejected and truly clean kaon spectra obtained.

TABLE I. COUNT RATE ESTIMATES/10 MeV

Target	E_e	E_e'	θ_e'	θ_K	θ_γ	Q^2	P_K	Rate/hr	Random/hr
D	2.5	1.2	12.5	12.5	11.5	0.15	.86	30	2
D	3.0	1.0	12.5	12.5	6.1	0.15	1.6	20	1.5
D	3.0	1.5	12.5	12.5	11.9	0.19	1.08	25	1.5
D	3.0	1.5	12.5	18.5	11.9	0.19	1.07	12	1.5
D	4.0	2.0	12.5	12.5	12.4	0.42	1.62	20	1.5
^{4}He	3.0	1.5	12.5	12.5	11.9	0.20	1.09	10	3.5

Energies and momenta in units of GeV, GeV/c; angles in degrees relative to beam direction.

TABLE II. TIME DIFFERENCES (ns) FOR KAON DETECTION IN SOS

p_K	β_K	β_π	β_p	$\Delta t(k-\pi)$	$\Delta t(k-p)$	$\Delta t(k-e)$
0.6	.772	.974	.54	6.6	13.7	7.3
0.9	.877	.988	.69	3.2	7.4	3.5
1.2	.925	.993	.79	1.8	4.6	2.0
1.5	.950	.996	.85	1.2	3.1	1.3
1.6	.955	.996	.86	1.04	2.7	1.16
1.8	.964	.997	.88	.84	2.2	0.9

RESOURCES

These studies require two spectrometers: 1) A moderate resolution ($dp/p<10^{-3}$) electron arm with solid angle 5-10 msr, angular resolution <0.5 mr, and a momentum acceptance >10%; 2) A kaon spectrometer with a solid angle ~10 msr, a momentum acceptance >20%, angular resolution <2 mr, but also being less than 10 meters long, to avoid excessive kaon decay losses; HMS and SOS are suitable.

COMMITMENT

The collaborators listed on the cover page have all expressed great interest in this program. Many of them have other interests in the CEBAF program, but consider the electroproduction of hypernuclei to be one of the primary areas for which there is unrivaled capability at CEBAF.

REFERENCES

1. T. W. Donnelly and S. R. Cotanch, CEBAF Summer Workshop 1985, pp 7-1; S. R. Cotanch, Research Program at CEBAF III, 1987.

2. S. R. Cotanch and S. Hsiao, Nucl. Phys. A450, 419c, (1986); SLAC Report No. 316, 127 (1987).

3. R. L. Jaffe, Phys. Rev. Lett. 38, 195 (1977).

FIGURE CAPTIONS

Fig. 1. Inclusive lab cross section for $d(e,e'K)(\Lambda n+\Sigma^0 n)$.

Fig. 2. Angular distributions for kaons illustrating the sensitivity to missing mass and the Y-nucleon final state interaction.[2]

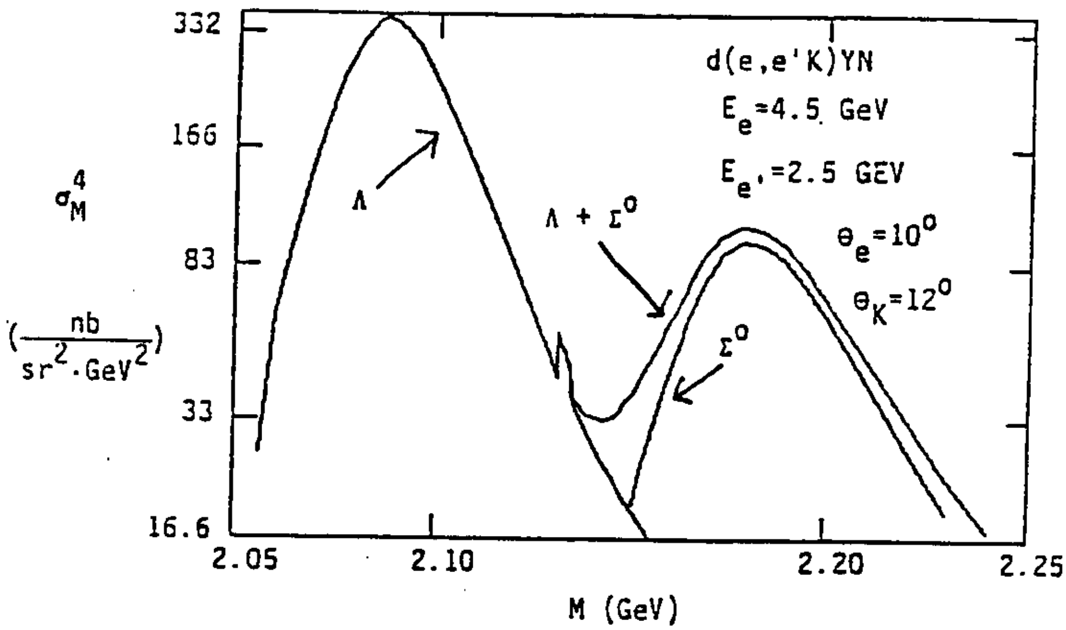

332
166
83
33
16.6
σ^4_M
$(\frac{nb}{sr^2 \cdot GeV^2})$
2.05
2.10
2.20
2.25
M (GeV)
d(e,e'K)YN
E_e=4.5 GeV
$E_{e'}$=2.5 GEV
$\theta_e=10^0$
$\theta_K=12^0$
Λ
Λ + Σ^0
Σ^0

Fig. 1

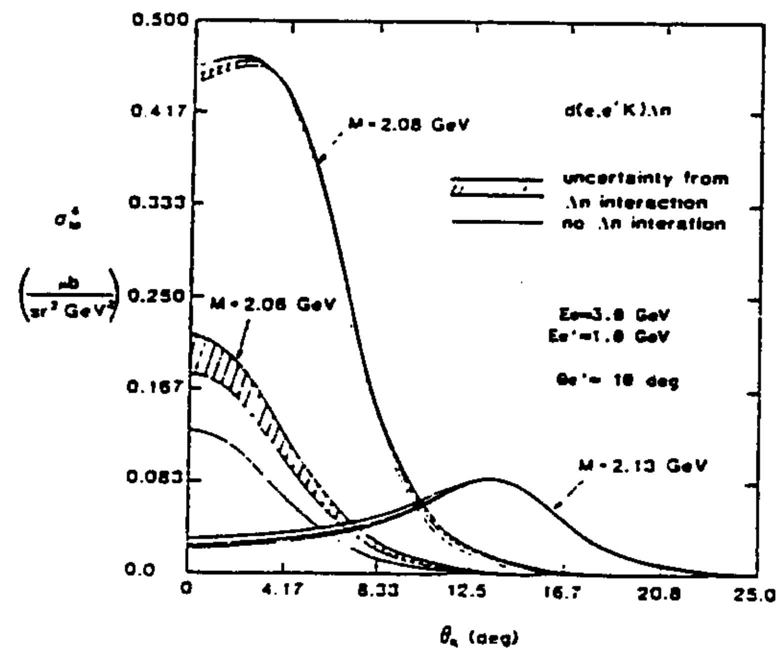
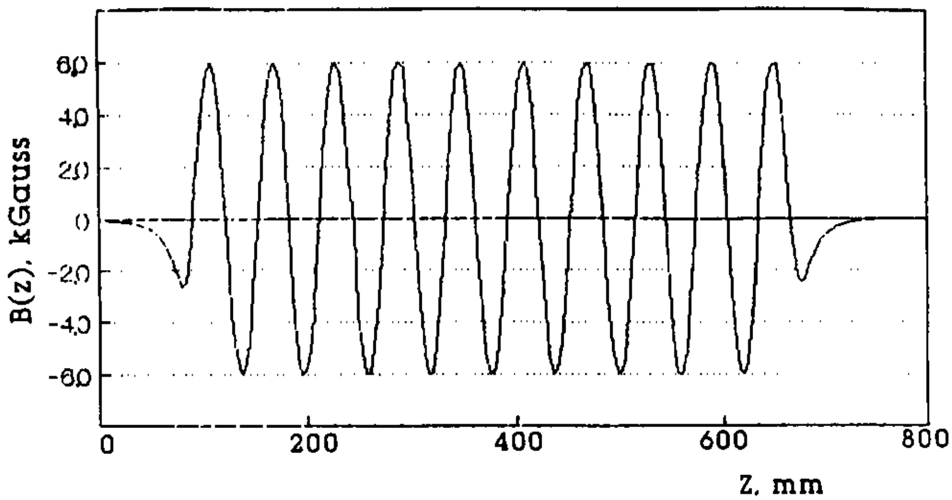
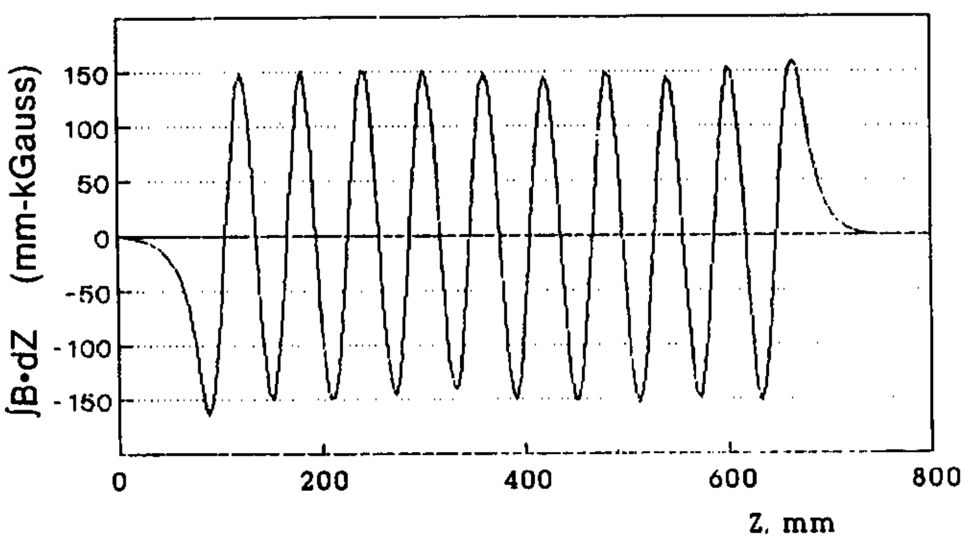

0.500
0.417
0.333
0.250
0.167
0.083
0.0
0
4.17
8.33
12.5
16.7
20.8
25.0
M = 2.08 GeV
M = 2.06 GeV
M = 2.13 GeV
uncertainty from
Λn interaction
no Λn interation

Fig. 2

On-axis magnetic field of KIAE hybrid udulator



First integral of on-axis magnetic field of KIAE undulator



Second integral of on-axis magnetic field of KIAE undulator